Flight Surgeon Refresher Course

Section 3: Aeromedical Training

Spatial Disorientation

(FSRC304)

SPATIAL DISORIENTATION

Introduction

From 1987 to 1995, 291 class A-C accidents were directly related to spatial disorientation. The results of these accidents were 110 fatalities and over 468 millions dollars in damage to the aircraft.

Objectives:

a. **List the mechanisms of equilibrium.**

b. **Describe the role of vision in spatial orientation.**

c. **List and describe visual illusions seen in aviation.**

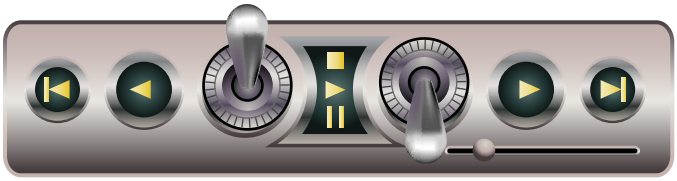
d. **Describe the function of the vestibular system in spatial orientation.**

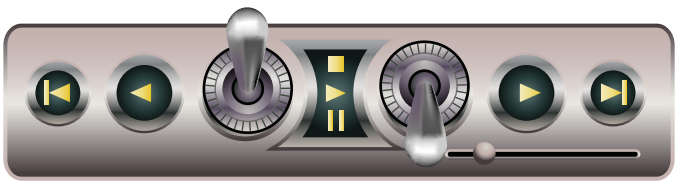
e. **List and describe vestibular illusions seen in aviation.**

f. **Identify the function of the proprioceptive system in spatial orientation.**

g. **Define the types of spatial disorientation.**

h. **Describe the corrective actions for spatial disorientation.**





Mechanisms of equilibrium:

Three mechanisms integrate to form a complete mental picture of orientation, and provide balance:

1. **Visual system**
2. **Vestibular system**
3. **Proprioceptive system**

Visual System

What is the role of vision in spatial orientation?

- The visual system is the most reliable system used during flight.
- 80% of orientation while flying is dependent on the visual sense.

What are the modes of vision?

The visual system has two modes of processing visual information:

Focal (Central) Vision:

- Focal vision is concerned with object recognition and identification.
- For instance, when we read a book or look at our flight instruments we are utilizing our focal vision.
- Focal vision cues provide the primary means by which judgments of distance and depth are made.
- The images we perceive throughout our lifetime are stored in memory so that we may compare their size to our own position relative to them.
- For example, a M32A2 2 ½ ton cargo truck is of a known size. Therefore, we can judge our distance from it, depending on its retinal projection.

Ambient (Peripheral) Vision:

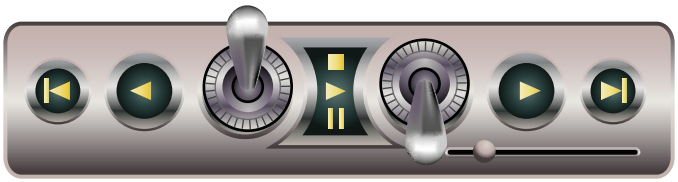
- Responsible for orienting us within our environment.
- It is the primary mode for detecting motion, although it has poor acuity properties.
- Its function is largely independent of the function of focal vision. One can fully occupy central vision with the task of reading while simultaneously obtaining sufficient orientation cues with peripheral vision to walk or ride a bicycle.
- In the absence of the horizon, visual cues arising in the ambient visual field can easily be misinterpreted and lead to disorientation.
- Peripheral vision provides adequate orientation information in absence of the perception of information from the vestibular apparatus.
- An individual can still maintain balance through the use of the peripheral visual mechanism of orientation.

Visual Illusions

Orientation by vision requires perception, recognition, and identification. In other words, a person must determine his position by understanding where other objects are in relation to himself.

Visual illusions may occur when visual cues are reduced by clouds, night, and/or other obscurities to vision. They include:

- Relative motion
- False horizons
- Height/depth perception
- Structural
- Fascination/fixation
- Size-distance



- Altered planes of reference
- Autokinesis
- Reverse perspective
- Crater illusion
- Confusion with ground lights
- Flicker vertigo
- Brownout/white-out

Relative motion illusion:

- The relative motion illusion is a falsely perceived self-motion in relation to the real motion of another object.
- The relative motion illusion can also occur to helicopter pilots hovering over tall grass. The rotor wash creates a continual waving motion, which makes it difficult to maintain a stationary hover point.
- The relative motion illusion can also occur during formation flight. The forward, aft, up, or down movement of a lead or trailing aircraft may be misinterpreted as movement of your own aircraft in the opposite direction.

False horizon:

- The false vertical and horizontal cues illusion can occur when the pilot unconsciously chooses the wrong reference point (i.e., clouds) for orientation information.
- A sloping cloud deck is difficult to perceive as anything but horizontal if it extends for any great distance in the pilot's peripheral vision.
- The pilot falsely perceives the cloud bank below to be horizontal. The cloud bank may not be parallel to the ground. The pilot then flies the aircraft in a banked condition parallel to the cloud bank, believing it to be the horizon.

Depth Perception Illusion:

- Due to a lack of sufficient visual cues, the aircrew member will experience the illusion that they are higher above the terrain than they actually are.

Example of relative motion illusion:

You are sitting in a car stopped at a stoplight and unconsciously reduce your scan outside the vehicle. Your peripheral (ambient) vision detects the motion of another car pulling up along side your car. You perceive the forward motion of the car beside you as the rearward motion of your own vehicle. Alarmed, you slam on the brakes.

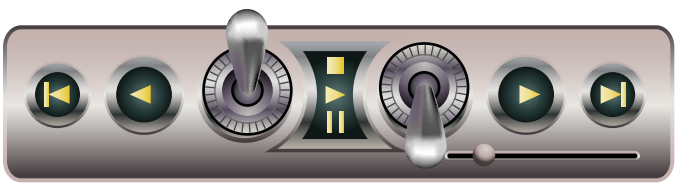
- Flying over an area devoid of visual references, such as desert, snow, or water will deprive the pilot of his perception of height.
- Flight in an area where visibility is restricted by fog, smoke, or haze produces the same illusion.

Structural Illusions:

- Structural illusions are caused by heat waves, rain, snow, sleet, or other visual obscurants.
- A straight line may appear curved when viewed through heat waves.
- Heavy rain against aircraft windshields may cause a pilot on half-mile final to perceive the runway as being 200 feet further away.

Fascination or Fixation:

- Occurs when aircrew members ignore orientation cues and focus their attention on their object or goal.
- Fascination may also occur during the accomplishment of simple tasks within the cockpit. Crewmembers may become so engrossed with a problem or task that they fail to properly scan outside the aircraft.
- Other types of fascination are associated with wheels-up landings, rigid fixation on the lead aircraft during formation flight, and over concentration on one instrument during instrument flight.
- Fixation is a specific type of fascination. In combat or at gunnery training, the pilot becomes so intent on hitting the target that he neglects to pull up in time to prevent impact with the ground.



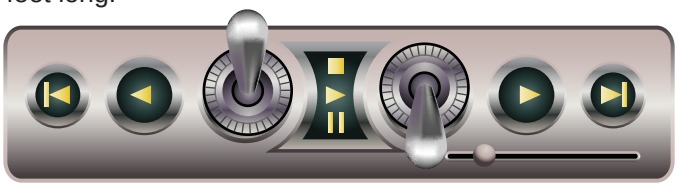
Visual Cues			
Geometric Perspective	**Retinal Image Size**	**Aerial Perspective**	**Motion parallax**
Use the acronym LAV: **L**-inear perspective. **A**-pparent foreshortening appears elliptical (narrow). **V**-ertical position in the field.	Use the acronym KITO: **K**-nown size of objects. **I**-ncreasing or decreasing size of objects. **T**-errestrial association. **O**-verlapping contours or interposition of objects.	Use the clarity of an object as seen through the atmosphere or the shadow that is cast by an object to determine its size and distance. Objects are seen less distinctly and appear to be at greater distance than they actually are when viewed through haze, smoke, or fog. An object is seen more distinctly and appears to be closer than it actually is in unrestricted atmospheric conditions.	One of the most important cues to depth perception is the apparent, relative motion of stationary objects as viewed by a moving observer. Near objects appear to move past or opposite the landscape. Far objects seem to move in the direction of motion or remain fixed. The rate of apparent movement depends on the distance the observer is from the object. Rapidly moving objects are judged to be near while slow moving objects are judged to be distant.

Size-Distance Illusion

- The false perception of distance from an object or the ground, created when a pilot misinterprets an unfamiliar object's size to be the same as an object he/she is normally accustomed to viewing.
- An aircraft hovering close by with its dim position lights on, may appear to be farther away than when viewed at the same distance with its lights on bright.
- This illusion also occurs if the visual cues, such as trees, are of a different size than expected. For example, the small trees of the mid-west have the same shape and contrast as the tall trees of the east coast. The pilot may fly his aircraft dangerously low, thinking that he is further away from the ground.
- A pilot may falsely perceive an unfamiliar LZ to be the same size as to which he is used to landing. For example, a pilot who is used to landing at an airfield with a large runway 200 feet wide and 5,000 feet long, may fly too low if making the same approach to a small airstrip of 100 feet wide, 2,000 feet long.

Altered Planes of Reference:

- The inaccurate sense of altitude, attitude, or flight path position in relation to an object very great in size so that the object becomes the new plane of reference rather than the correct plane of reference: the horizon.
- A pilot approaching a line of mountains may feel the need to climb although his altitude is adequate. This is because the horizon, which helps the pilot maintain orientation, is subconsciously moved to the top of the ridge line. Without an adequate horizon, the brain attempts to fix a new horizon.
- Conversely, an aircraft entering a valley, which contains a slowly increasing up-slope condition, may become trapped because the slope may quickly increase and exceed the aircraft's ability to climb above the hill, causing the aircraft to crash into the surrounding hills.
- When flying next to large cloud formations, the eyes may interpret the cloud formations as a horizon. The tendency would be to tilt away from the clouds (false horizon illusion).



Autokinesis:

- Results when a static light appears to move when it is stared at for several seconds.
- Uncontrolled eye movement may possibly cause the illusion of movement as the eye attempts to find some other visual reference points.
- This illusion is particularly profound when siting a red light at night.

Reversible Perspective:

- At night, an aircraft may appear to be going away when it is actually approaching. This illusion is often experienced when an aircrew member observes an aircraft flying a parallel course.
- To determine the direction of flight, the aircrew member should observe the position of the aircraft lights (Red, right, return)

Crater Illusion:

- When landing at night, the position of the landing light may be too far under the nose of the aircraft.
- This will cause the illusion of landing into a hole (crater).

Ground Light Confusion:

- Pilots have put their aircraft in unusual attitudes to keep ground lights above them; having mistaken the ground lights for stars.
- By establishing a true horizon and attitude through instruments this can be avoided.

Flicker Vertigo:

- Can be caused by the sunlight flickering through the rotor blades or propellers or by rotating beacons reflecting against an overcast sky.

Brownout/white out:

- Dust or snow obscure visual cues

Vestibular System

What is the role of the vestibular system?

- Located in the middle ear
- Provides the sense of balance and orientation
- Visual tracking
- Reflex information
- Orientation without vision

Semi-circular Canals:

- Right angles to each other.
- Contain endolymph fluid.
- Responsive to angular acceleration. Detect change in both speed and direction.
- Detects yaw, pitch, and roll in three dimensions.

Otolith Organs:

- Stimulated by gravity and linear accelerations.
- Sense a change in speed without a change in direction.
- Sensitive to linear acceleration and deceleration (forward, aft, up, and down.)

Vestibular Illusions

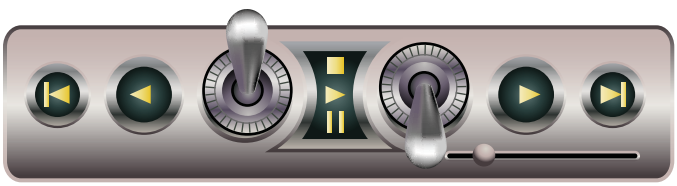
Vestibular illusions occur when either the Semi-circular Canals (Somatogyral illusions) or the Otolith Organs (Somatogravic illusions) receive altered inputs as a result of the flight environment. These illusions are overwhelming, and it takes a disciplined pilot to trust his instruments to overcome them.

Somatogyral Illusions (Semi-circular canals)

- The Leans
- The Graveyard Spin and Spiral
- Coriolis

Somatogravic (Otolith Organs)

- Oculogravic
- Elevator
- Nystagmus (vestibulo-ocular interaction)



The Leans

This illusion is based on the principle that the hair cells in the semi-circular canals will extinguish a signal after about 20 seconds, leading him to believe that he is wings level when he is in fact turning. After correcting to wings level, he will erroneously experience a sensation of turning. Movement of the endolymph is most noticed when there is a *change* in the stimulus!

1. Pilot enters unperceived bank (sub-threshold maneuver)
2. Refers to instruments
3. Corrects aircraft attitude
4. Conflict between mechanisms of equilibrium
5. Pilot compensates by leaning in direction of original bank

The Graveyard Spin and Spiral

The only difference between the Graveyard Spiral and The Leans is that the pilot corrects for his vestibular conflict by providing flight control input in the direction of the original bank (instead of just leaning). This leads to an increasingly steep angle of bank and a deadly spiral straight into the ground. In extreme cases he will induce a spin.

Coriolis

This illusion is based on the "cross-coupling" effect when two or more semi-circular canals are simultaneously stimulated. This usually happens with a head movement during an instrument approach or bombing run while looking in one direction and turning the aircraft in another. This is truly a provocative illusion!

1. Pilot enters a turn stimulating one semicircular canal
2. Pilot makes a head movement in a different geometric plane
3. An additional semicircular canal is stimulated
4. Results in overwhelming sensation of Yaw, Pitch, and Roll simultaneously

Oculogravic Illusion

Upward movement of the eyes during weightlessness, caused by rapid downward motion of the aircraft.

The downward movement of the aircraft, leaves the eyes lagging (looking up relative to the aircraft). This creates a sensation that the aircraft is diving.

The converse illusion may occur in which the aircraft receives an updraft with eye movement downward creating a sensation of climbing.

Elevator Illusion

On sustained forward acceleration (e.g. take off roll in a jet), the otolith organ is stimulated. This causes a nose up sensation and an urge to push the control stick forward into a dive. For this reason, procedures call for Fighter Pilots to place their hands on the instrument panel (away from the flight controls) in plain view during catapult launches off of aircraft carriers!

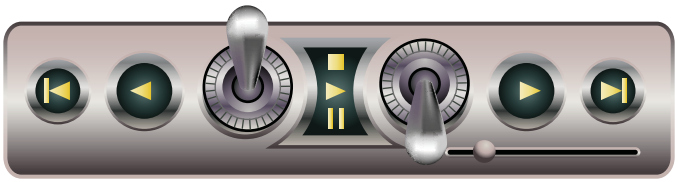
Nystagmus (vestibulo-ocular interaction)

Involuntary rapid oscillations of the eyes in a horizontal, vertical, or rotary direction.

Proprioceptive System

What is the role of the Proprioceptive System?

- Awareness of position, weight, and changes in equilibrium
- Cues provided by receptors throughout the body
- "Seat of the pants" flying.
  - Unreliable means of orientation
  - Dependent on gravity and inertia
  - Flying without reference to instruments



Spatial Disorientation

Spatial disorientation is the leading cause of aircraft mishaps in the US Army today. Spatial disorientation contributes more to aircraft accidents than any other physiological problem in the aerial environment.

It can strike at virtually anytime and place and in any mode of flight.

Definition. The inability to correctly determine one's position, attitude and motion of an aircraft in flight relative to the surface of the earth or other significant objects.

Spatial Disorientation is:

The inability to correctly determine one's position, attitude and motion of an aircraft in flight relative to the surface of the earth or other significant objects.

Types of Spatial Disorientation?

Type I - Unrecognized

- Aircrew member does not perceive disorientation of any kind.
- Dies with a smile on his face.

Type II - Recognized

- Aircrew member realizes a problem exists. If he is able, he turns the controls over to another pilot.

Type III - Incapacitating

- Aircrew member experiences an overwhelming physiological response to physical or emotional stimuli associated with spatial disorientation.
- Panic, freezing on the controls.

Dynamics of Spatial Disorientation

Visual Dominance

- A learned phenomena whereby one uses focal visual cues while excluding other sensory cues.
- Very complex and fragile skill. Can be lost due to events that disrupt concentration on flying the aircraft.
- Acquired through training.

Vestibular suppression

- Active process of visually overriding undesirable vestibular sensations.
- An example of vestibular suppression: when a figure skater stops spinning and doesn't feel dizzy or overcome by nystagmus.

Vestibular opportunism

- The propensity of the vestibular system to fill an orientation void swiftly.

What are measures that help prevent spatial disorientation?

- Education and training
  1. Simulators
  2. Classroom instruction
- Maintain visual references
  1. Actual horizon.
  2. Artificial attitude indicator.
  3. Never fly VMC and IMC at the same time. Don't "feel" for the ground once visual contact is lost.
- Aircraft procedures
  1. Trust your instruments
  2. Aircrew coordination training
- Avoid self-imposed stress.

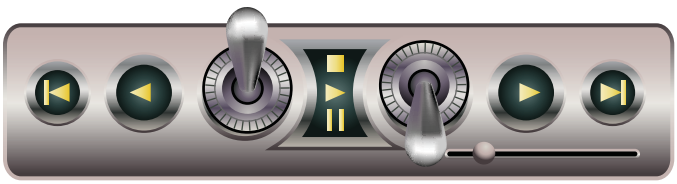
Counteracting spatial disorientation:

Ensure the instruments read right!!

Delay intuitive reactions.

Never fly both VMC and IMC at the same time

Transfer the controls as the situation dictates



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